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EARTHQUAKES.

BY W. T. BRIGHAM.

EARTHQUAKES and volcanoes are at last claiming, by their very intrusive activity, the attention of observers, who are able to look through the smoke of an eruption, and the dust of an earthquake, at the real geological importance of the terrible demonstration. Within the past two years the earth has been strangely unquiet. First Vesuvius sputtered forth feebly in its old age; then Santorini smoked and steamed, and extended its little territory; then Central Europe shook a little, and the tremor extended through Asia, and into the Pacific, where a new island came to the surface near the Samoan Group. All these were but premonitions, and last spring, while the vibrations were being repeated on the eastern continent, the huge volcanoes of the Hawaiian Islands broke forth with a violence unknown there for centuries. The earth heaved and opened, the craters of Kilauea and Mauna Loa poured forth their lava streams, and finally the sea rushed upon the shore destroying animals and men. To this day the island shakes, but the movement is so slight that little notice is taken of it. Not so remarkable as this Hawaiian earthquake, nor so admirably adapted for scientific research, but far more destructive to life and property, was the terrible earthquake of the South American coast this summer. The commotion was so violent, that the impulse given to the sea extended through the whole Pacific, reaching even to the coast of Kamtschatka.

While the scratches of the pebbles, frozen into a block of ice, claim and gain the attention of geologists, strangely enough, the far mightier forces which build up those mountain ranges, and which have modified much of the earth's crust, are comparatively neglected. It is true that M. Alexis Perrey, in France, has collected since 1842, all evidence attainable relating to earthquakes, which he has published

in annual catalogues; and Robert Mallet, in England has collected similar evidence in his "Catalogue of Recorded Earthquakes, from 1606 B. C., to A. D. 1842," and has done a very important work in his investigation of the great Calabrian Earthquake of 1857. With these exceptions, very little of importance has been done to investigate the causes and seasons and effects of earthquakes; and geologists do not as yet know whether the shock is caused by the falling of huge masses of rock into subterranean caverns, by the explosion of gasses pent up in the bowels of the earth, by the evolution of steam when water reaches the heated interior of the globe, by the surges and tides of an inner molten sea, acted upon by the moon's attraction or terrestrial revolution, by the gradual contraction of the earth's cooling crust, by the waxing and waning of the internal heat locally, by some unknown law, or by any of the other causes so ingeniously suggested, most of which are as probable as the subterranean convulsions of an imprisoned Titan.

Catalogue makers have to trust to evidence which has become more or less distorted in passing through many hands; they do not see for themselves. When an earthquake takes place, everybody is caught unprepared, and if not killed, yet so terribly frightened, as to be wholly unfit to describe events exactly as they took place. The evidence of one good observer, who examines the ground after it has all passed, is of more value than a score of newspaper reports at the time. But our geologists all live far away from earthquake countries, and only a return to the shakes, which took place in New England a century ago, will wake them up to the importance of seismic* studies. Let us not feel too secure among our granite hills.

New England has been visited by a number of earthquakes since the Pilgrims landed in 1620. The first was in 1638, and twenty years later occurred what is called a "great earthquake," but no descriptions have been preserved. In

* *Seismic* means relating to earthquakes; from *seismòs*, an earthquake.

1663 (February 5), a severe shock was felt in Canada, New England, and New York, severe enough to open and shut doors, ring bells, split walls, and let floors fall through; and while the first shock continued nearly half an hour, a most uncommon thing, the secondary shocks continued at intervals until July. In 1727, an earthquake occurred in the territory between the Delaware and Kennebec rivers, centreing, apparently, near the Merrimack river. Springs changed their place, and some dried up; the water in wells was rendered turbid and unfit to drink, so that people pumped the wells dry thinking some carrion had fallen in. November 18th, 1755, a shock threw down about a hundred chimneys, and about fifteen hundred were shattered more or less in Boston. The ends of twelve or fifteen brick buildings were thrown down from the top to the eaves of the house. The duration of the shock was nearly four and a half minutes. On the same day the sea withdrew from the harbor of St. Martin's, in the West Indies, leaving vessels high and dry, and on its return the waves rose more than six feet above high-water mark. This was nine hours after the shock was felt in Boston. Since then no severe shocks have been felt in New England, although a band of extinct volcanoes extends through its midst, curving from Montreal to New Jersey.

These gentle breathings of Mother Earth become terrible gasps and spasms in other regions, and as examples of her terrible power, the earthquake of Lisbon, and the repeated shocks of the Andean region, may be here recalled.

November 1st, 1755, about half past nine in the morning, a sudden subterranean noise was heard, and in a few seconds the principal buildings of Lisbon were in ruins. It was a *fete* day, and the churches were crowded; the high steeples and the solid walls fell together, and thousands of people were crushed beneath the ruins. People in the upper stories of the houses were generally more fortunate than those below, or in the streets, but it was believed that sixty thousand perished on this terrible day in Lisbon. To add to the hor-

rors of the scene fire broke out among the ruins, a violent wind arose, and in about three hours the city was reduced to ashes. Immediately after the shock, a huge wave entered the Tagus, forty feet higher than the water had ever been known to rise before, but the bay received most of its violence, and it at once subsided. The quay was thronged with people, and it suddenly sank, and no body ever floated to the surface. Where the solid wall had stood the water was many fathoms deep. At Cadiz the sea wave was nearly sixty feet high, and did great damage. According to Humboldt's computation, a portion of the earth's surface, four times greater than all Europe, was simultaneously shaken; even our great lakes felt the commotion, and tides of considerable height were observed on their shores.

During the years 1811-12, earthquakes were felt in South Carolina, and more violently in the valley of the Mississippi, where, at New Madrid a whole grave-yard was pitched into the river; and the violence finally culminated in the destruction of Carracas, burying ten thousand of its inhabitants beneath its ruins. In 1835, an earthquake was felt between Copiapo and Chiloe on the north and south, and the island of Juan Fernandez, and the city of Mendoza, on the west and east. Concepcion, Talcahuano, Chillan, and other towns were thrown down, and immediately after the shock the sea retired in the Bay of Concepcion, and the vessels grounded where had been seven fathoms of water. A wave soon rushed in and retreated, and was succeeded by two others probably not more than sixteen or twenty feet in vertical height. In November 1837, Valdivia, in Chili, was destroyed, and in January of the same year a shock devastated Syria, destroying more than six thousand people, and making itself felt over a territory five hundred miles long by ninety wide.

The earthquakes, then, of the present year are no novelties, however dreadful they may seem, but they offer many interesting features, and although no scientific man has yet published any account of the earthquake of St. Thomas, that

of the Hawaiian Islands, or of Peru, it may be well to briefly recount the facts.

At St. Thomas no less than five hundred shocks of earthquake were felt, from the middle of November to the second of December, 1867. The inhabitants had abandoned their houses, and dwelt in tents on the hill-sides. November 18th was a clear, beautiful day, the ocean was almost calm, and the sun was bright and warm. Not a sign foretold the approaching catastrophe, when at a quarter before three in the afternoon, the usual underground rumbling was heard as of distant thunder, and immediately the earth rose and fell in small waves for about a minute, while the subterranean noise was dreadful. No one could stand. The sun seemed to have lost his power. After the first shock, the ground kept quivering for about ten minutes, when another strong shock was felt. Before the first shock, the ocean had receded several hundred feet from land, and it now returned as a huge, straight, white wall, smooth and even as a wall of masonry, and eighteen to twenty-five feet high. It moved with considerable velocity, upsetting all small craft, and raising large vessels to its top. The lower part of the shore was submerged to a depth of two or three feet, and to a distance of two or three hundred feet inland. An even larger wave succeeded this, at an interval of about ten minutes, and as this passed away, the ocean remained calm as before the first shock.

At St. Croix, the U. S. steamer *Monongahela* was thrown high and dry upon the shore. The waves receded rapidly, and at once rose in a wall nearly thirty feet high, white as snow, and hissing with spray. This huge wave carried everything before it, and it was repeated several times with nearly equal violence, when, as at St. Thomas, the sea became quite still.

Between 4 and 5 o'clock, P. M., on Thursday, April 2d, 1868, an earthquake occurred on Hawaii, centreing on the southern slope of Mauna Loa, far severer than before re-

corded on the group. Houses were destroyed, cliffs hurled down, fissures opened in the ground, the whole earth seemed in violent motion, and an earthquake wave drove the sea over the southern coast in places to a height of twenty feet, sweeping away all the shore villages. Five days later lava broke out on the higher slopes of Mauna Loa, and flowed into the sea. Kilauea, at the moment of the great earthquake of April 2d, began to empty itself by some subterranean channel, and is now five hundred feet deeper than in 1865. This whole eruption and earthquake, more remarkable than any of the others of the past year, deserves a fuller description than can be given here. The newspaper reports are filled with errors and misstatements.

Finally, in this series of disturbances, we have the terrible earthquake which, on the 13th of August last, caused so great destruction of life and property on the coasts of Chili, Peru, and Ecuador. At Arica, lat. $18^{\circ} 30'$ S., long. $70^{\circ} 25'$ W., the rumbling sound as of distant thunder, so usual a forerunner, preceded this earthquake, and almost immediately the rocking motion of the earth commenced. Houses trembled with increasing force, until they fell in crashing ruin. The earth opened in several places in almost regular clefts from one to three inches wide, and as these closed they sent a cloud of dust to mingle with that from the falling buildings. Gas of a most suffocating nature, came from these fissures, and had it remained long, all animal life must have perished, but after three undulations, each severer than the preceding one, the cloud of dust and gas which overhung all, dispersed, and the light again appeared. The gas remained in all about a minute and a half. Quakes at short intervals succeeded, and subterranean explosions, and now all the survivors fled to the hills, taking their most precious property, for the sea was fast receding, and they well knew the terrible consequences of that unnatural tide. Soon the current changed, the ocean came back in a huge wall of water, dragging with it all the vessels, among them the large U. S. steamer Wateree

which was landed almost uninjured about four hundred and fifty yards inland. The other vessels did not fare so well: dashed ashore, keel upmost, they remain a sad spectacle, the prey of the wreckers. On shore less than a hundred people lost their life, while on shipboard nearly three hundred perished. At Iquique the shock lasted over four minutes, and was followed by the wave which destroyed at least three-quarters of the town and many lives. At Arequipa the earthquake commenced a few minutes past five in the afternoon, and in a few moments nearly every house in the town was in ruins. The cities of Yca and Pisco suffered severely, and at the Chincha Islands both the earthquake and the tidal wave did great damage. At Callao the wave went over the houses on the shore at 10 o'clock, P. M. These were much damaged, but no lives were lost. At Talcahuano, and Torne, near Concepcion, three shocks occurred, a day later according to the reports, and the second caused, or was followed by a tidal wave, which nearly destroyed the towns. From Cape San Francisco, in Ecuador, to the Straits of Magellan, nearly every seaport town has suffered, and at the northern end of this coast line, among the mighty volcanoes of the equator, the records report several towns in ruins, among them Ibarra, San Pablo, and Atuntaque, and where Catacachi stood is now a lake of water. No less than thirty thousand inhabitants of these towns perished with their homes.

Let us close this sad catalogue of disasters, where man seems so utterly powerless to cope with the vast forces with which God's plan of creation is carried on, with a brief review of some of the former earthquakes, which have rendered this region so noted.

According to Ulloa, in 1570, along the coast of Chili, an earthquake and tidal wave was felt which extended three hundred leagues along the coast. In 1575 Valdivia was destroyed. January 22d, 1582, at noon, Arequipa was destroyed, and four years later, at Callao, a tidal wave four-

teen fathoms high followed a severe quake, and extended two leagues inland. In 1600, Arequipa was covered with ashes from a neighboring volcano. In 1605, November 26th, Arequipa was destroyed, and the sea overwhelmed Arica, leaving a few streets only. In 1678, at Santa, some 5° N. of Callao, the sea retired a long distance, returning with great force, and destroyed the town. Four years later Pisco was destroyed by a tidal wave. Six years rest, and Pisco was again inundated, and in 1690, after a very violent shock, the sea retired six miles, and after three hours returned with such rapidity that the fleetest horses could not save their riders; the earth sank, and where the town stood is the present harbor. In 1705, Arica was destroyed by a tidal wave, and ten years later was nearly overturned with Arequipa and other towns by earthquakes. The next year, 1716; the town of Pisco, which had been rebuilt farther inland, was again destroyed, and now not by a tidal wave, for although the sea was so agitated that masts and yards of vessels were shattered, it did not pass its bounds. July 8th, 1730, Concepcion was destroyed by an earthquake and tidal wave. At Callao in 1746, a severe earthquake was felt, and the tidal waves were of great size; of twenty-three vessels then in port, seventeen were sunk, and four carried inland above the town, which was levelled by the waves. Of four or five thousand inhabitants, only two hundred survived, and on the second advance of this vast wave, only a portion of the wall of the fort, which preserved twenty-two persons, remained. In 1773, at Copiapo and along the coast, the earthquake claimed 45,000 victims. May 15th, 1784, Arequipa was overturned, and several districts hitherto arid, produced springs of water, so abundant as to form navigable streams. In 1828, at Callao, an English vessel, the *Volage*, found the water boiling about her, and exhaling a great quantity of sulphuretted hydrogen. Many dead fish floated; on weighing anchor portions of the cable twenty-five fathoms from the ship, lying on a bottom of soft

mud, were found partly melted. Arica this time wholly escaped, although the shocks were felt all over Peru. In 1831, after nearly a century's rest from any fatal shocks, Arica was destroyed for the fifth or sixth time since the landing of the Spaniards, some three hundred years since. These are only the most severe shocks which have disturbed this region. Others, that anywhere else would attract attention, here pass almost unnoticed. Indeed it has been said that the Andes are continually quaking in some part, although severe shocks have seldom visited the eastern slope.

The volcanoes nearest the cities of Arica and Arequipa are of great height; *Sahama*, near the former, being 23,914 feet, while *Miste*, near the latter, is 18,877 feet high, and frequently in gentle eruption.

With such an array of terrible results, it would be hard here to insist, with any chance of being believed, that earthquakes are, by no means, nuisances, and, that on the contrary, they are portions of God's operations in Nature most beneficial and useful. The tides of the ocean are useful, that every one knows, although they leave bare and pestilent marshes and flats; and these irregular tides of the land have none the less their uses in breaking up and altering the surface of the earth, changing watercourses, altering the shoreline, and in other ways, whose description can hardly be condensed into the limits of this article.

REVIEWS.

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*The Variation of Animals and Plants under Domestication. By Charles Darwin. Authorized (American) Edition, with a Preface by Professor Asa Gray. 2 vols, 12mo, pp. 494 and 500. Published by Orange Judd & Co., 245 Broadway, New York.